Mars Pathfinder

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General Mission Overview

Mars Pathfinder, launching in December 1998 and landing on Mars on July 4, 1997, will demonstrate a low-cost delivery system to the surface of Mars for follow-on landers. Historically, spacecraft that orbit or land on a distant body carry a large amount of fuel for braking at the planet. Pathfinder requires fuel only to navigate to Mars; the spacecraft aerobrakes Into the Mars atmosphere, deploys a parachute at 10 km above the surface and, within 100 m of the surface, fires solid rockets for final braking prior to deployment of airbags that cushion touchdown. After landing, petals open to upright the lander.

The major objective of Pathfinder-am+dsltion and return of engineering data on entry, descent, and landing (EDL) and lander performance-will be completed within the first few hours after landing. In addition, the lander will transmit panoramic images of the Martian surface the first day. Next, a microrover will be deployed, as early as the first day, to perform mobility tests; image its surroundings, including the lander; and place its Alpha Proton X-Ray Spectrometer (APXS) against a rock to make elemental composition measurement.

While Pathfinder is an engineering demonstration, it accomplishes a focused, exciting set of science and technology investigation with a stereo, multi-color lander Imager; atmospheric instrumentation, used as a weather station after landing; the APXS; and the microrover Including its aft and forward cameras.

The Pathfinder flight system is a blend of available and new technology, and each application is carefully weighed as to its contribution to performance, risk and cost. Pathfinder is being developed in a special "cheaper, better, faster" project operating mode, accomplishing a challenging mission at low cost and fixed price, using a "Kelly Johnson"-like skunkworks approach, focusing on a limited set of objectives, and streamlining project approaches and minimizing bureaucratic interference, NASA'S Office of Space Science is developing Pathfinder, The Advanced Concepts and Technology Office teamed with the Space Science office to develop the Pathfinder rover. Pathfinder is being performed at the Jet Propulsion Laboratory (JPL) in its in-house, subsystem mode.

An important feature of Pathfinder's approach is collocation of key team members on the same floor of one building around e test bed. Collocation simplifies lines of communication and facilitates rapid iteration of requirements, and resolution of issues and problems. Ibam members from the JPL technical divisions remain administratively tied to their home divisions, in what is called the "soft projectized mode", but are responsible to the project rather than to the divisions for performance, cost and schedule of their work packages. The Project is self-contained, including collocated product assurance and procurement teams.

Pathfinder uses the following available equipment or designs:

- Cassini transponder
- Magellan star scanner
- Adcole Corporation sun sensors
- Viking heritage aeroshell and parachute designs
- DOD-developed rocket assisted deceleration (RAD) rockets and altimeter

All flight equipment is being subjected to rigorous inheritance review and to space qualification testing tailored to the Pathfinder mission regardless of previous testing history

Initial tests of the retrorocket system were completed successfully in Maroh 1995 at the China Lake Naval Testing StatIon in California. These tests showed that the retrorocket system was conceptually sound and could provide the required performance on Mars. This testing is required to ensure that Pathfinder is ready for launch.

Testing Is critical to the success of Pathfinder, Assembly, Test and Launch Operations (ATLO) began on June 1 of this year to assemble the spacecraft quickly and maximize the amount of test time before launch. The ATLO phase will take about 18 months, more than twice the primary mission duration (7 months of cruise time pi us 1 month of surface operations), The flight system will acquire up to 2000 hours of testing, effectively "burning In" the electronics before the launch,

In the spring of 1996, system-level environmental tests will be performed, including thermal/vacuum, acoustic, and static load tests. The rover will be included In all flight system tests and will also be subjected to surface operations tests in a simulated Mars environment at JPL.

There are also plans for an extensive series of entry, descent, and landing tests. Pioneer Aerospace Corporation successfully tested the low-attitude parachute. At the NASA Lewis Research Center's Plum Brook vacuum chamber In Ohio, ILC Dover Company tested the airbag drop in a simulated Mars atmosphere, And JPL will conduct final tests of the retrorocket system, as well as airbag retraction and lander uprighting.

Pathfinder's key new technology uses include:

- A tree-ranging microrover with on- board autonomous navigation
- A solid-state X-band power amplifier
- A radiation-hardened Loral RS6000, 32-bit flight computer
- Airbags adapted for use in Mars atmosphere
- Lender. Image data compression

The microrover, X-band power amplifier and EDL (in particular the airbags) represent the major Pathfinder developments, and significant work was accomplished on each of these in the pre-Project phase including proof-of-concept airbag tests at Sandia National Laboratory, microrover mobility tests and breadboard power amplifier development at JPL.

The EDL system is comprised of subsystems with heritage requiring little or no development (the airbags being the exception), and the challenge lies with incorporating these into,an effective, space-qualified system. While EDL system demonstration and qualification testing are of major importance, they are not on the critical path relative to ATLO and can be accomplished largely independently, in parallel with ATLO. ATLO critical path items include the lander structure, harness, power subsystem, Attitude and information Management (AIM) subsystem which embodies the central computer, and attitude control and command and data handling functionality.

Technical Mission Description

The Pathfinder flight system, with an approximate launch massof819 kg (1802 lbs) will be launched to Mars in the period December 2 to December 25, 1996 from a McDonnell Douglas Delta II rocket, landing on July 4, 1997. The flight system is spin stabilized during cruise, spinning at 2 rpm, with the spin axis and medium-gain antenna pointed to Earth except for the first 20 days after launch, when the spin axis is pointed closer to the sun line. After the first 20 days, the sun line remains within 40 degrees of Earth, and the earth point attitude is maintained until Mars atmosphere entry, including cruise trajectory maneuvers which are performed in either the vector mode thrusting along or perpendicular to the spin axis, or the "turn and bum" mode. All cruise critical events are telemetered in real time to Earth

Twenty four hours before Mars arrival, the flight system will turn approximately 7 degrees to its entry attitude and, keeping in touch with Earth, will Jettison its cruise stage (reducing its entry mass to 537 kg) and enter directly into the Mars atmosphere, braking with an aeroshell (140 kg) , parachute (17 kg), small solid retrorockets (34 kg) and airbags (77 kg).

The entry velocity is 7.8 km/s (17,1 00 mph) compared with Viking at 4.6 km/s which entered from orbit, Mars Pathfinder entry angle is 16,7 degrees (90 degrees would be straight down) and peak atmospheric shook, 25 g's, is encountered at 32 km above the surface. The parachute is deployed by mortar at Mach 1.8 (900 mph) at 10 km, 100 seconds after atmospheric entry. Ames Research Center In Moffett Field, California, has are-jet tested the Viking SLA 561 ablative material used on the aeroshell, to insure it can withstand the extra heat pulse due to the larger entry velocity.

The NASA Langley Research Center In Hampton, Virginia, accomplished the aerodynamic analysis for entry and descent and supported design of the parachute, a Viking-derivative disk-gap-band design with a 12.7 m diameter, Its canopy is constructed of polyester (Dacron) and it has Kevlar suspension lines. Early proof-of-concept tests were accomplished at the Sandia National Laboratory in the spring of 1992, and follow-up tests were conducted in the summer of 1994. Sandia also consulted on the parachute design.

EDL engineering telemetry will be transmitted to Earth in real time to the extent possible. Before chute deployment, Earth remains near the spin axis behind the craft, and communication to Earth is through a low-gain antenna at 40 bits per second. After chute deployment, the Earth moves to approximately 90 degrees from the spin axis including chute swing, making communications more difficult. EDL, lasting for 5 minutes, will be supported with the NASA Deep Space h/etwOk'870 m antenna,

As the lander descends into the Martian atmosphere, it will deploy from the backshell onto a 20 m bridle, constructed of woven Kevlar. As it approaches the surface the RAD rockets fire at a thrust of 7938 n for 2.2 s in order to slow the vehicle even further, the bridle is cut, the airbags inflate to 1.65 psi and the lander drops the final 30 m to the surface. Once on the surface, the airbags deinflate in about 1.5s and retract under the lander over a period of 1.5 hours. The vehicle will then right itself by deploying petals that expose solar panels to the Sun for powering surface operations,

The landing site itself is located just beyond the mouth of Ares Vallis (1 9,5° N, 32.8" W) in southern Chryse Planitia, or about 1000 km from the Viking 1 landing site. it was selected to maximize the chances of having a wide diversity of rook types within view of the lander camera and accessible to the microrover. Flood channels such as Ares Vallis transported sand to large boulder-size debris eroded from the bedrock all the way from the channel source to its mouth, This site can be considered a "grab bag" site, in which the lander can characterize a wide variety of the rocks that make up the martian crust, which are essentiality unknown at present. Rocks carried by the Ares Vallis floods include ancient highlands crust and intermediate-age volcanic rocks, which will help us understand the differentiation of the planet (into crust, mantle, and core). Most importantly for the lander, less than 1 % of the rocks are estimated to be greater than 1 m in diameter, At landing, the season at this northerly latitude on Mars will be late summer',

After landing, the lander will transmit stored EDL data and real-time lander and microrover engineering telemetry first. Panoramic images of the surface will also be transmitted to Earth the first day. The microrover will be deployed as early as the first day, for start of its surface operations. The microrover conducts surface mobility experiments, images rocks and soil, and deploys the APXS on soil and against rocks. While 30 sol (1 sol = 1 Martian day = 24.6 hours) and 7 sol primary surface missions are planned for the lander and microrover, respectively, close to 100?4 of all lander and microrover engineering and science objectives are achieved nominally In the first few sols of surface operations. No constraint precludes operations of the lander or the microrover past their primary mission requirements

SURFACE OPERATIONS SEQUENCE

Event	Sol	LST hh:mm	Date	GMT hh:mm	Time a landing Hrs	Time a landing Min
Land	1	3:14	7/4/97	01:15	0	0
Airbag retraction	1	3:59	7/4/97	02:01	0	46
let Earth rise, 20° mask	1	4:13	7/4/97	02:15	1	0
Petal Opening (possible carrier link)	1	4:44	7/4/97	02:47	1	32
Establish oomm with Earth, elev=55°, L(3A at 40 b/s	1	6:53	7/4/97	05:00	3	45
1st Sunrise, 20° mask	1	7:08	7/4/97	05:15	4	0
Complete downlink EDL telemetry	1	7:53	7/4/97	06:01	4	46
Establish 1st comm on High Gain Antenna (HGA), data rate=1260 b/s	1	8:47	7/4/97	06:57	5	42
Complete downlink panorama portion for rover deploy	1	10:23	7/4/97	08:35	7	20
Establish accurate oomm on HGA, data rata-5530 b/s	1	12:37	7/4/97	10:53	9	38
Complete downlink imager for Mars Pathfinder (IMP) pre-deploy panorama	1	13:28	7/4/97	11:46	10	30
Deploy Rover	1	13:29	7/4/97	11 :46	10	31
Rover Image of lander	1	13:44	7/4/97	12:02	10	47
Rover image of soil	1	13:56	7/4/97	12:14	10	50
APXS on soil	1	14:03	7/4/97	12:21	11	6
Complete downlink rover image of soil	1	14:03	7/4/97	12:21	11	6
1st Earth set, 20° mask	1	14:11	7/4/97	12:30	11	15
1st Sunset, 20° mask	1	16:51	7/4/97	15:14	13	59
Rover image of rook	2	11:28	7/5/97	10:22	33	7
Complete downlink rover image of rook	2	11:44	7/5/97	10:38	33	23
Complete downlink IMP post-deploy planning panorama	2	12:40	7/5/97	11:36	34	21
Complete downlink rover image of lander	2	12:42	7/5/97	11:38	34	23
Complete downlink APXS soil data	2	12:43	7/5/97	11:39	34	24
APXS on rook	3	10:20	7/6/97	09:51	56	36
Complete downlink APX6 rock data	4	7:26	7/7/97	07:32	78	17
Complete rover technology experiments (finish rock APXS)	4	7:26	7/7/97	07:32	78	17
Complete lander primary mission objective (end of 801 4 downlink)	4	14:11	7/7/97	14:28	86	13

The Pathfinder scientific payload includes instrumentation for measuring atmospheric and landing deceleration; pressure and temperature during entry and while on the surface; a 12 spectral channel, stereo lander camera for surface and atmospheric imaging, including imaging magnetic properties targets, a wind sock mast and support of microrover navigation; and the microrover-deployed APXS for elemental composition measurements of rocks and soil. The microrover carries aft and forward cameras for demonstrating autonomous hazard avoidance and imaging Its local surroundings, soil and rooks, and the lander.

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